Firm: CFD Research Corporation, 215 Wynn Drive, Huntsville, Alabama 35805
Contract Number: NNX11CH36P
Project Title: FREE-SURFACE MODELING OF CRYOGENIC FLUIDS USING A HIGHER-ORDER, UNSTRUCTURED GRID VOLUME-OF-FLUID (VOF) METHOD

Identification and Significance of Innovation: Accurate and efficient computational modeling of free-surface flows has numerous applications of current and future relevance to NASA. Modeling technology for free surface flows currently available to NASA engineers has several limitations. It is limited with respect to mesh topology and solution accuracy, does not accurately incorporate phase change across the free surface and is not scalable for highly parallel simulations. In this project, CFDRC and Streamline Numerics will develop and implement, in Loci-Stream, an innovative and improved VOF methodology with the following advanced features: (1) Ability to handle triangle and quadrilateral cell types in 2D, and tetrahedral, prism, hexahedral and general cell types in 3D; (2) Spatially second-order surface reconstruction for these cell types; (3) Hybrid implicit-explicit time integration scheme that both maintains a sharp interface and allows realistic time steps for the overall flow solver; (4) Phase change across liquid-gas interfaces; and (5) Highly efficient parallelization with scalability to thousands of processors. To demonstrate feasibility in the Phase I project a previously developed 2D stand-alone VOF module has been coupled to Loci-Stream and validated.

Technical Objectives and Work Plan: (Limit 200 words or 2,000 characters whichever is less)
The overall goal of this SBIR project (Phase I and II) is to develop, implement and validate in Loci-Stream a high-fidelity and computationally efficient module to simulate free-surface flows using an innovative and improved VOF methodology. In this Phase I project the aim was to demonstrate the feasibility of implementing and validating the 2D Loci-Stream-VOF coupled code. This work will provide the necessary experience and the foundation needed for the Phase II implementation and validation of 3-D higher-order time-accurate VOF in Loci-Stream.

The specific Phase I objectives were:

1. Formally verify the second-order spatial accuracy of the Loci-based VOF interface tracking module previously developed by CFDRC.
2. Couple the Loci-based stand alone VOF module to Loci-Stream.
3. Show the feasibility of the proposed approach by validating the coupled 2-D Loci-Stream-VOF code.

Technical Accomplishments: (Limit 200 words or 2,000 characters whichever is less)
All technical objectives were accomplished. This work will provide the necessary experience and the foundation needed for the Phase II implementation and validation of 3-D higher-order time-accurate VOF in Loci-Stream.

NASA Application(s): (Limit 100 words or 1,000 characters whichever is less)
Potential applications for NASA and contractors include: (1) sloshing of liquid fuels in fuel tanks; (2) extrapolation of slosh experiments to cryogenic fluids; (3) propellant tank stage separation dynamics; (4) design of anti-vortex baffles; (5) thrust oscillation impact on upper stage ullage collapse; (6) water pooling dynamics associated with launch pad water deluge; (7) propellant tank pressurization processes and many others.

Non-NASA Commercial Application(s): (Limit 200 words or 2,000 characters whichever is less)
The proposed computational tool will be beneficial to gas turbine engine and diesel engine manufacturers, and has applications in fuel injector design for power plants and in industrial boilers/burners. The tool will also be relevant to chemical industry applications involving flows with phase change, phase separation, and heat and mass transfer.

Name and Address of Principal Investigator:
Dr. Ranjan S. Mehta
CFD Research Corporation
215 Wynn Dr.
Huntsville, AL 35805

Name and Address of Offeror:
CFD Research Corporation
215 Wynn Dr.
Huntsville, AL 35805